Demo: Dead Reckoning for Monte Carlo Localization in Low Seed Density Scenarios

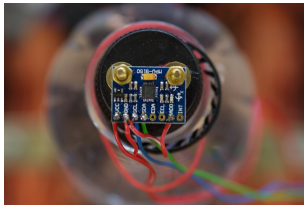Arne Bochem   Andreas Zdziarstek   Salke Hartung   Dieter Hogrefe
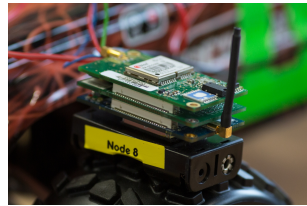
Institute of Computer Science, Telematics Group
University of Goettingen, Germany
{bochem, hartung, hogrefe}@cs.uni-goettingen.de

(a) MPU-9150   (b) Full mote stack

Figure 1: Mobile node hardware components.

Abstract

In this work we present a dead reckoning approach called Sensor-Assisted Monte Carlo Localization (SA-MCL) to account for low seed density situations in localization for mobile sensor networks. Our approach is based on using additional sensor information from a standard IMU device. It is evaluated in a mobile sensor network testbed based on radio-controlled cars. The demo complements our full paper which describes our localization solution in detail.

Keywords

Wireless Sensor Network, Mobility, Localization, Dead Reckoning, Range-Free, Monte Carlo Localization

1 Introduction

Localization is a mandatory requirement in Wireless Sensor Networks (WSNs). Since GPS is not a sufficient solution due to various drawbacks, such as high energy-consumption and only working in outdoor scenarios, the concept of using anchor nodes in combination with location estimation algorithms has been developed. A major problem of this approach is the dependence on seed information, which might not be available due to disconnected or temporary isolated nodes in the network. In these cases proper localization is impossible which results in a high localization error. To cir-

cumvent this problem, we developed a dead reckoning solution based on additional sensor information to update the position of a node based on its last known location. We implemented our solution on top of a popular range-free localization solution called Monte Carlo Localization (MCL).[1, 3]

2 Methodology

Monte Carlo Localization (MCL) is a range-free localization approach that employs a particle filter to estimate the locations of sensor nodes in a WSN. When seed nodes, which broadcast location announcements and are usually equipped with GPS, are within range, only particles that are inside the seed nodes' communication range are kept. Additionally, the neighbours of seed nodes announce when they are able to hear seed nodes. Using this second-hop information, particles that fall into twice the communication range around those nodes are also kept.[3]

MCL works well enough with high seed densities, but in scenarios with a low seed density, its performance quickly declines. We implement a new technique based on MCL called Sensor-Assisted Monte Carlo Localization, which adds low-cost and low-power IMUs to sensor nodes. This allows us to perform dead reckoning during periods where no seed nodes can be heard by a node and no second-hop seed information is available. This scheme improves on the localization accuracy of MCL, especially with low seed densities, thus lowering cost of deployment.[2]

We experimentally verify the validity of our approach in a field test with ten remote controlled cars, equipping cars with IRIS sensor nodes, a GPS sensor to measure the ground truth and an MPU-9150 9-axis IMU. Figure 1 shows individual
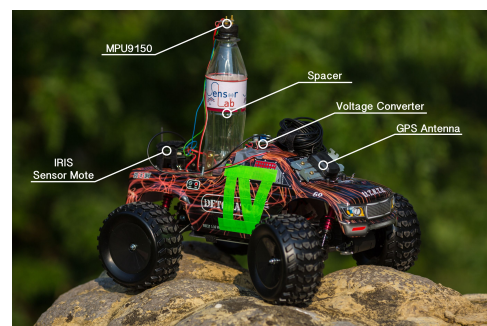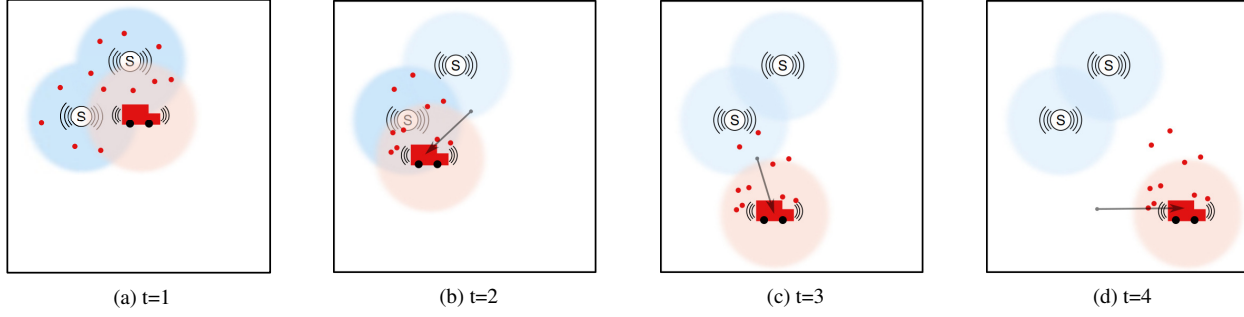
Figure 2: Fully assembled RC car mobile node.

| (a) t=1 | (b) t=2 | (c) t=3 | (d) t=4 |

Figure 3: Particle movement in SA-MCL inside and outside the range of seed nodes.

Figure 4: Average grid error over all cars.

Figure 5: Path taken by RC car during experiment.
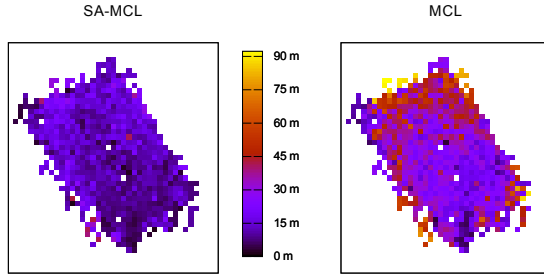
parts while Figure 2 shows the fully assembled RC car.

Figure 3 visualizes the resampling of the particles while seeds are in range and, starting with t=3, the movement of particles along the vector determined by dead reckoning.

3 Results

During the field test, we determined the average absolute localization error of SA-MCL to be 11.37 m, while for MCL it is 27.1 m. This corresponds to an average improvement of 58 %, with a maximum of 66 %. Even in the worst case, there is an improvement of 46 % when comparing SA-MCL to MCL.

Additionally, we define a second metric for measuring error, called grid error. For the purpose of this metric, the experimental area is split into cells sized $\approx$ 3 m $\times$ 3 m and the average error for each cell is then determined by averaging the error of all location estimates produced during the experiment, for which the ground truth falls into this cell. Since interpreting the results of this metric easier when presented in a visual style, a heat map representation is provided in Figure 4, which shows that MCL mostly performs well near the bottom of the experimental area, where the cars were close together at the beginning of the field test, while SA-MCL performs well over the whole area.

4 Demo Scenario

For our demo, we use a simplified scenario with static seed nodes containing hardcoded coordinates that are placed around the demo area. Two RC cars are driven over the demo area while their estimated locations are visualized on a real time display. Additionally, the recently taken paths for both cars are displayed in a way similar to Figure 5. To showcase the performance differential between MCL and SA-MCL, we limit seed nodes to a low radio range and place them less
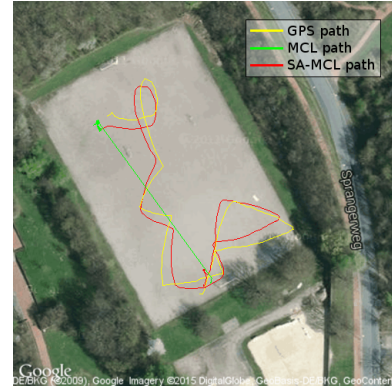
densely in some parts of the area. An abstract schematic of the demo setup can be seen in Figure 6.

5 Conclusion

We present and evaluate Sensor-Assisted Monte Carlo Localization (SA-MCL). Experimental evaluation shows an improvement of up to 66 % over MCL. Especially in scenarios with low seed densities, we find SA-MCL to significantly outperform MCL.
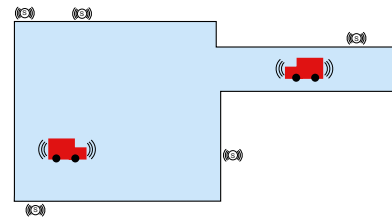

Figure 6: Setup of demo with seeds and RC cars.

6 References

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